



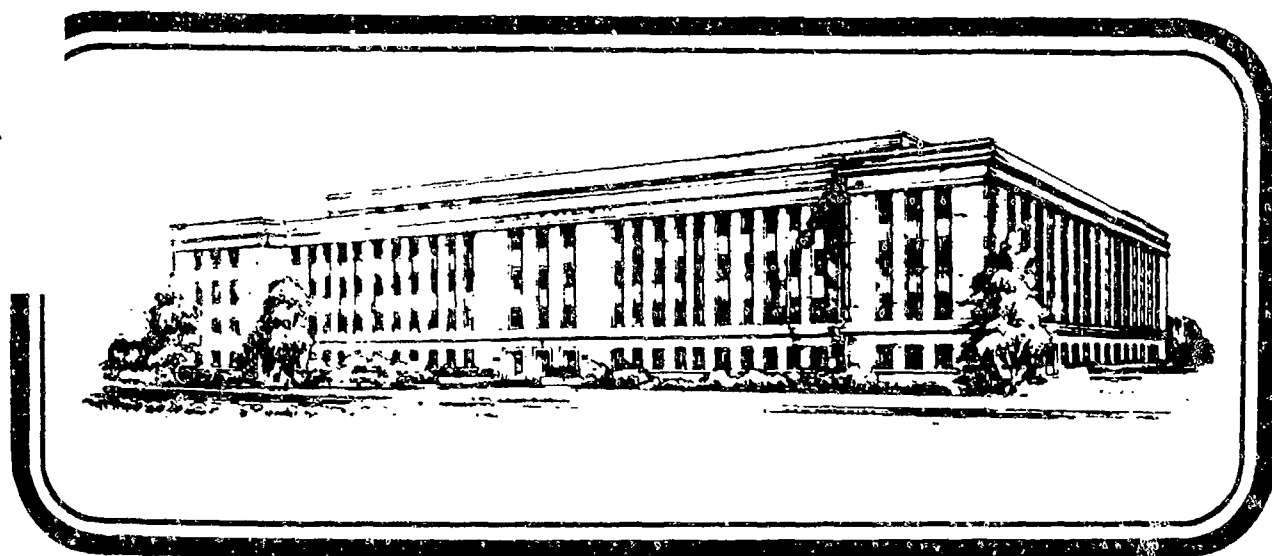
NATIONAL DEFENSE UNIVERSITY

1-11-84
②

**MOBILIZATION AND DEFENSE MANAGEMENT
TECHNICAL REPORTS SERIES**

**THE USE OF REACTIVATION NETWORKS TO
IMPROVE MOBILIZATION PREPAREDNESS
OF THE AMMUNITION INDUSTRY**

AD A138165



DTIC
SELECTED
FEB 23 1984
E

INDUSTRIAL COLLEGE OF THE ARMED FORCES

This document has been approved
for public release and sale; its
contents are unlimited.

\$4.02 22 009

DTIC FILE COPY

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NDU/ICAF 83/014	2. GOVT ACCESSION NO. AD-A138 165	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE USE OF REACTIVATION NETWORKS TO IMPROVE MOBILIZATION PREPAREDNESS OF THE AMMUNITION INDUSTRY		5. TYPE OF REPORT & PERIOD COVERED IR #16, AY 82/83
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) DAVID M. PUJMAN, COL, USA		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS INDUSTRIAL COLLEGE OF THE ARMED FORCES FORT LESLEY J. MC NAIR WASHINGTON, DC 20319		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS INDUSTRIAL COLLEGE OF THE ARMED FORCES FORT LESLEY J. MC NAIR WASHINGTON, DC 20319		12. REPORT DATE MAY 1983
		13. NUMBER OF PAGES 62
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) NATIONAL DEFENSE UNIVERSITY FORT LESLEY J. MC NAIR WASHINGTON, DC 20319		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) UNLIMITED APPROVAL FOR PUBLIC RELEASE		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) N/A		
18. SUPPLEMENTARY NOTES N/A		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) N/A		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The report concerns the ways in which use of network analysis and computer modeling can improve the state of preparedness of the ammunition industry. It focuses in particular on the Venture Evaluation and Review Technique and progress being made to use the technique to build models of ammunition production lines. A brief history of the development of the U.S. ammunition industry from Word War II to the present is included, and some of the anomalies of munitions production are explained. Emphasis is placed on the ability to reactivate ammunition production		

20. facilities under emergency conditions.

The report concludes that network analysis is a practicable means to improve industrial preparedness, and recommends additional measures that if implemented could make the technique more effective.

NATIONAL DEFENSE UNIVERSITY
INDUSTRIAL COLLEGE OF THE ARMED FORCES

MOBILIZATION STUDIES PROGRAM REPORT

THE USE OF REACTIVATION NETWORKS
TO IMPROVE MOBILIZATION PREPAREDNESS
OF THE AMMUNITION INDUSTRY

by

COL David M. Pojmann, USA

A RESEARCH REPORT SUBMITTED TO THE FACULTY
IN
FULFILLMENT OF THE RESEARCH
REQUIREMENT

RESEARCH SUPERVISOR: COLONEL KAY KIMURA, USA

INDUSTRIAL COLLEGE OF THE ARMED FORCES

MAY 1983

DISCLAIMER-ABSTAINER

This research report represents the views of the authors and does not necessarily reflect the official opinion of the Industrial College of the Armed Forces, the National Defense University, of the Department of Defense.

This document is the property of the United States Government and is not to be reproduced in whole or in part without permission of the Commandant, the Industrial College of the Armed Forces, Fort Lesley J. McNair, Washington, D.C. 20319.

ABSTRACT OF STUDENT RESEARCH REPORT INDUSTRIAL COLLEGE OF THE ARMED FORCES

NAME OF RESEARCHER (S)

COL David M. Pojmann

TITLE OF REPORT

The Use of Reactivation Networks
To Improve Mobilization Preparedness
Of the Ammunition Industry

SECURITY CLASSIFICATION OF REPORT

Unclassified

REPORT NUMBER

M

ABSTRACT

The report concerns the ways in which use of network analysis and computer modeling can improve the state of preparedness of the ammunition industry. It focuses in particular on the Venture Evaluation and Review Technique and progress being made to use the technique to build models of ammunition production lines.

A brief history of the development of the U.S. ammunition industry from World War II to the present is included, and some of the anomalies of munitions production are explained. Emphasis is placed on the ability to reactivate ammunition production facilities under emergency conditions.

The report concludes that network analysis is a practicable means to improve industrial preparedness, and recommends additional measures that if implemented could make the technique more effective.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



THIS ABSTRACT IS UNCLASSIFIED

FOREWORD

Contrary to popular opinion, something is being done to improve mobilization preparedness of the ammunition industry. One can sift through myriad reports collecting dust that all seem to reach the same conclusion--something has to be done about industrial readiness. Even the minions of preparedness are becoming most adept at self-flagellation, having joined the chorus of auditors, critics and "watchdogs" who unceasingly demean the ability of American industry to respond to a national emergency, and it is becoming increasingly difficult to find managers who think things are getting better. One reason for this attitude is that we tend to look at the entire spectrum at once and it boggles the mind. The shortcomings of the preparedness posture stand out and the positive aspects are often overlooked.

My intention when I began this report was to determine if anything positive is being done to improve the readiness of the ammunition industry. I found that the US Army Armament Materiel Readiness Command (ARRCOM) at Rock Island, Illinois is working on two networking systems that are intended to improve production management and efficiency of the government-owned ammunition plants and the preparedness posture of laid away government facilities. The first approach, called Manufacturing Resource Planning (MRP), is an expanded centralized scheduling system that controls all material flows through the manufacturing process. The second networking approach, called Venture Evaluation and Review Technique, third generation (VERT-3) is a method being used to develop computer simulation of laid away ammunition facilities.

The original approach was to compare the two techniques to find out if they are complementary or otherwise related, but research into both techniques led to the conclusion that they have different objectives and different forms of implementation. The MRP system is a production scheduling and inventory control system¹ that will be very useful in the day-to-day operations of the ammunition plants. The system will also have a beneficial impact on mobilization production, but it is not specifically a mobilization technique. I could not see an immediate correlation between MRP and VERT, although some future amalgamation may be possible. The implementation of MRP is progressing well and the technique is already successful in several private US industries. On the other hand, VERT-3 has had less publicity and is not as well known as MRP. It is still developing, and in the current application is directly related to mobilization preparedness. I decided to limit this report to the effects of the application of VERT on the preparedness of the ammunition industry.

¹Oliver Wight, The Executive's Guide to Successful MRP II (Englewood Cliffs: Prentice-Hall, 1982), p. 2.

I was first introduced to VERT in 1981 as the commander of the Kansas Army Ammunition Plant, Parsons, Kansas. At that time, I was intrigued by the possibilities of the technique, but I was pessimistic about the chances of success of the program. It seemed to be an extremely complicated system that offered job security for a bevy of technicians, but few opportunities for management manipulation. I was wrong. The VERT process, while virtually unknown to most managers in the ammunition industry, may well be a sleeping giant ready to revolutionize our approach to industrial preparedness. Research for this report has convinced me that VERT-3 is applicable not only to reactivation of ammunition lines, but also may have many other military applications. The use of this modern technique, coupled with lessons learned from previous wars could improve preparedness while saving millions of dollars.

To understand why network models can help improve industrial readiness it is necessary to look at the historical perspective of the ammunition industry and to gain an appreciation for the complexity of the present system. Therefore, before treating the networking model, this report explores how the system developed and discusses briefly the complexity of the ammunition industry and the environment that confronts decisionmakers in dealing with industrial preparedness.

EXECUTIVE SUMMARY

The US Army Armament Materiel Readiness Command (ARRCOM) at Rock Island, Illinois is experimenting with a networking system using a process known as the Venture Evaluation and Review Technique (VERT) to better assess the state of readiness of laid away ammunition production facilities. The technique shows promise to at least identify, if not correct, readiness deficiencies that could add to the time needed to react to an emergency.

The present ammunition production complex developed out of the necessity to prepare for World War II. Plants were scattered at random throughout the country. Safety considerations and the need to build the plants as rapidly as possible caused design criteria which did not necessarily promote the most efficient means of production. The government lacked sufficient management expertise when the building began to both build and operate the plants, so the Army turned to private industry to provide the necessary management talent to operate the plants. The result was an organization of government-owned, contractor-operated plants, which has persisted to the present time. The uncertainty of production requirements for ammunition tends to discourage private investment in production facilities completely dedicated to the government's needs. There is, however, a network of suppliers who furnish most of the raw materials and many of the manufactured parts that are required to produce ammunition.

The complexity of the system and the uncertainties of requirements have led to doubts concerning the system's ability to meet mobilization requirements. To insure a production capability for the future, the Army began a long term modernization program which includes one completely new plant and improvements to dozens of production lines. Automation, mechanization, and modernization have increased production capability and overall readiness, but some doubt still exists concerning the ability of the system to react in time to produce sufficient ammunition before war reserve stocks run out.

There are still many uncertainties facing decisionmakers in the ammunition industry, and it is difficult to insure that all the necessary inputs will be available on time to support production under mobilization conditions. Every decision that can be made before mobilization will reduce the time needed to mobilize. Every uncertainty that can be eliminated will also improve the decision process. One way to improve the decision-making process is to build models of the systems that will have to be activated or reactivated. Reactivation networks which are supported by computer-based analysis can contribute significantly to the readiness posture. The problem until recently, however, has been the inability to construct models in which time, cost and performance data could be manipulated to determine the effects of each on the others.

A system known as PERT, for Program Evaluation and Review Technique, has been used for several years by government and industry for planning complex projects. The Graphic Evaluation and Review Technique (GERT) was developed in

the early 70's as another method of project management. Both systems use networking techniques and have given good results when applied to some very complex developing systems, such as the Polaris submarine program. PERT is a deterministic method; it is unable to determine the probability of the most likely event occurring in a given network. The method is not able to treat cost as a variable. Cost impact can be estimated, but the system itself cannot manipulate cost data.

GERT is a stochastic method which is able to determine the most optimistic, most pessimistic, and most likely outcomes of a given network. Like PERT, GERT is limited in its ability to handle costs. Cost is treated as a non-decisive element. This is a serious deficiency when dealing with reactivation networks wherein the costs of maintaining war reserve stocks must be compared with the costs of increasing the state of readiness of particular ammunition production lines.

The Venture Evaluation and Review Technique (VERT) was conceived in the early 70's and is still developing. The third generation, known as VERT-3 is being used by ARRCOM to model its reactivation networks. VERT-3 is a stochastic method, which by a series of iterations can predict the probability of success of any given event in the network. The VERT method can also treat cost as a variable, along with time and performance criteria. VERT is designed as an open-ended and comprehensive system that establishes relationships among network parameters. One of the major strengths of VERT is that it allows performance to be entered into the network in numerical terms rather than merely as total alternatives.

The need to provide large quantities of ammunition with relatively short warning time has increased in recent years when our nuclear advantage over the Soviet Union diminished. Planners just a few years ago believed that if a war lasted more than a few months, we would resort to nuclear weapons to end it and there was not a great need to prepare to produce large quantities of conventional ammunition. In a situation wherein the other side has the nuclear advantage, it would not be in our best interest to initiate nuclear operations. We must, therefore, be prepared to support our forces indefinitely with conventional munitions. Reactivation networks will provide the means to optimize the trade-offs between maintaining large stocks of war reserve munitions or providing the means to reactivate production facilities.

Even though the production facilities are laid away, the reactivation requirement is not static. In fact, it is a very dynamic situation. Facilities deteriorate with age, ammunition is consumed in training, and contractors leave and enter the production system. Funding is subject to the vagaries of the planning system as well as to economic and political considerations. The advantage of using reactivation networks is that once a network is developed, changes caused by the environment can be entered quickly and at a relatively low cost. Updating will insure that decisionmakers are as well informed as possible on the inputs and outputs that affect their decisions. The decisionmaking process itself should be speeded up considerably.

One of the major obstacles to the successful implementation of the networking process within the ARRCOM complex is that the process itself is not comfortable for most managers. There is not widespread understanding among those involved as to what the system can do for them. This lack of understanding and the fact that there are no long range goals associated with the program could cause the program to fail in spite of the fact that it has very great potential to make a significant contribution to readiness.

A plan to link all the production facilities through networks was conceived in 1978. The initial effort, which requested that all the plants develop networks, gave the plants very little guidance as to what was expected of them. That attempt failed to produce the desired results, so it was necessary to start a fresh effort using a standard approach. The new effort did not attempt to involve all the plants. Instead, Kansas AAP was used as the lead plant and three other plants; Indiana, Riverbank, and Holston, are developing networks based on a proposed ARRCOM pamphlet developed by Day and Zimmermann, Inc., operator of the Kansas plant.

The use of VERT networks could streamline much of the reporting that is presently required from both government and private producers. The process of updating the networks would provide instant information to decisionmakers without the need to interpret information provided in various formats in the hundreds of reports currently processed by ARRCOM. There is much that can be accomplished through the use of the VERT process, but first there is a need to inform and train managers to use the system. Until managers understand it and feel comfortable with it, VERT will only be another unused technical tool.

TABLE OF CONTENTS

CHAPTER	PAGE
DISCLAIMER-ABSTAINER.....	ii
ABSTRACT.....	iii
FOREWORD.....	iv
EXECUTIVE SUMMARY.....	vi
I. HISTORICAL BACKGROUND.....	1
II. THE AMMUNITION PRODUCTION COMPLEX.....	12
III. DECISIONMAKING.....	19
IV. REACTIVATION NETWORKS.....	24
V. INDUSTRIAL PREPAREDNESS MANAGEMENT.....	28
VI. VENTURE EVALUATION AND REVIEW TECHNIQUE.....	36
VII. OPERATIONS WITH VERT.....	40
VIII. WHAT NETWORKS CAN ACCOMPLISH.....	46
IX. CONCLUSIONS....	52
X. RECOMMENDATIONS.....	56
ACRONYMS AND ABBREVIATIONS.....	58
BIBLIOGRAPHY.....	59

CHAPTER I

HISTORICAL BACKGROUND

One of the most urgent needs during armed conflict is a supply of ammunition adequate to last until a favorable end to the conflict is achieved. Modern weapons are capable of expending huge quantities of ammunition in very short periods, and a war with an armed force the size of the Soviet Union's military could quickly use up the war reserve stocks of ammunition. The security of the United States compels our society to provide a capability to produce large amounts of ammunition after a relatively short warning period.

In World War I the United States had most of its ammunition supplied by allies. There was ample warning time to develop an ammunition production capability before committing US forces to battle, but the amount of ammunition produced by the United States during WWI was relatively small compared to that produced by either our allies or adversaries.

WWII was raging for some time in Europe before the United States entered the war in December 1941. US arsenals had produced weapons and ammunition for the British and Russians before any US troops were committed to the war. In fact, the building of the first new US ammunition plant during WWII was financed by the British.¹

¹Berkely R. Lewis, "Ammunition, 1 July 1940 to 31 August 1945," History of the Ordnance Department in World War II, Monograph No. 4 (Washington: Office of the Chief of Ordnance, 31 December 1945), p. 37.

When the United States began preparations to make ammunition for WWII, it had to rely on a half-dozen government owned and operated arsenals which had not been substantially upgraded since WWI, as maintaining munitions factories during a period of peace was anathema to the American public. A report issued by the US Army Chief of Ordnance in 1945 indicates the state of readiness of the US ammunition industry when the war began:

"During the years of peace, there were but meager appropriations for keeping research up-to-date and for planning to meet a national emergency. And the techniques and "know how" of World War I were inadequate for the highly specialized mass production of World War II."²

At the beginning of the Second World War the United States was largely dependent upon Picatinny Arsenal at Dover, New Jersey, and Frankford Arsenal in Philadelphia, Pennsylvania, for its artillery and small arms ammunition. Production expertise and know-how were lacking. There were only 375 regular Ordnance officers in the Army in the summer of 1940.³ The government did not have the civilian technicians or managers knowledgeable in ammunition production, or the capability to manage the network of ammunition plants that would be needed to supply the country's armed forces in Europe, Africa, and the Pacific. The Army turned to private industry for help and industry responded rapidly and effectively. By the time the Japanese struck Pearl Harbor, dozens of ammunition plants were under construction across the United States. A concept of government-owned, contractor-operated (GOCO) plants was established and that relationship has endured to this date.

²Ibid., p. 3.

³Harry C. Thomson and Lida Mayo, The Ordnance Department: Procurement and Supply (Washington: Dept. of the Army, 1960), p. 108.

Many of the nation's chemical companies and heavy industries assumed management control of the newly-built plants, but even such unlikely arms builders as Proctor and Gamble and Quaker Oats responded to the call for help. By mid-1942, most of the GOCO facilities were reaching full production. Chemical plants for munitions production were built to produce powder and explosives without placing a burden on existing private facilities, which continued to produce for the civilian economy. Metal parts plants were built to provide shells and bomb bodies, and load assemble and pack (LAP) plants were established to assemble complete rounds for shipment overseas. Depots were built to hold the overflow during slack periods in the war.

The main considerations in picking locations for plants was that they be inland and safe from direct enemy attack. Other considerations included remoteness from major population centers, adequate land (plants averaged about 18,000 acres in area) and a trainable labor force. Political considerations did have a bearing and sometimes caused the selection of some less desirable sites. Rural areas near cities of 15,000 to 30,000 population were favorite plant sites. The decision to disperse the plants over wide areas may have seemed a good one at the time, but has resulted in a system that is remote from major ports and major industrial areas.

The GOCO concept had many advantages, but dual control by government and industry produced duplication of effort and many opportunities for friction developed.⁴ Contractors with limited knowledge of ammunition had to be trained by the few knowledgeable Ordnance officers and government

⁴Ibid., p. 126.

technicians. The plants were established as military reservations and commanding officers were assigned, but responsibilities were not clear and frequent rotation of commanding officers added to the turmoil. One plant had seven different commanders over three years.⁵ Responsibility for payroll, time-keeping, and other record keeping initially rested on the government staffs, but eventually it was shifted to the contractors and the number of government employees at GOCO plants was cut in half between January 1943 and June 1944.⁶

The illustration in figure 1 depicts the complexity of the ammunition production network. The system must be synchronized to maximize effectiveness and minimize waste of time and resources.

Because each plant specialized in a particular phase of production, inputs from several widely dispersed plants were necessary to produce a single item. For example, a 105mm howitzer round produced at the Kansas Ordnance Plant (now Kansas Army Ammunition Plant) at Parsons, Kansas, required powder bags and brass casings from two plants in Indiana, explosive from Tennessee, a projectile body from Alabama or Pennsylvania, and a fuze from any of a number of vendors. Packaging materials came from several sources, primarily in the South. The finished rounds would then be shipped to a port in either New Jersey, South Carolina or California. If this seems like a complex network, keep in mind that the 105mm projectile is a fairly simple munition and over 93 million rounds were produced during WWII.⁷ If the 105mm line at Parsons were

⁵Ibid.

⁶Ibid., p. 127.

⁷Lewis, p. 12.

PROCUREMENT AND PRODUCTION OF AMMUNITION

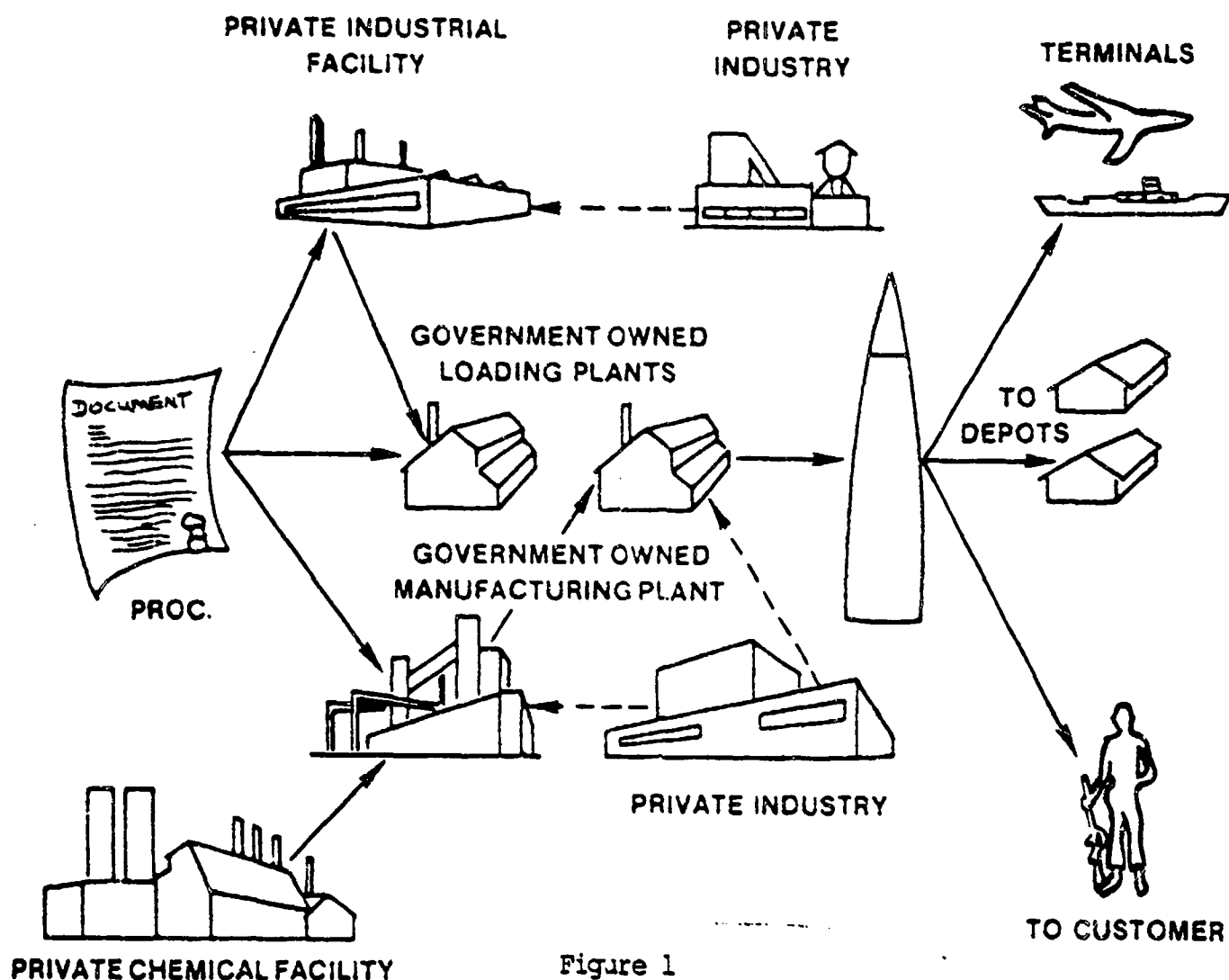


Figure 1

Source: ARRCOM's Management of Its Ammunition Plants.

This chart graphically illustrates the fragmentation of the basic ammunition procurement order and the interrelationship between private industry (prime contractors), private industry (subcontractors), and the government manufacturing and government loading plants. All actions throughout this complex operation are scheduled on a time phased basis to meet the ultimate objective to support end item requirements.

reactivated today, the same situation that existed in WWII would apply. All components would be shipped in from various points in the US, and completed rounds would be shipped out.

The speed with which government and industry pulled together toward the production goals was nothing short of amazing, but there was much uncertainty and waste in gearing up for wartime production. Even after production was well underway, requirements varied widely and some lines were shut down and restarted several times. Bomb production is a case in point. At the beginning of the war, bomb requirements were determined on the number of aircraft expected to be produced, and the number of sorties each could be expected to fly. Ammunition plants were constructed and equipment procured on that basis. By 1943 there was a glut of bombs because planners failed to take into account aircraft in the supply pipeline, training, and other uses. Drastic reductions in bomb production were ordered in 1943, causing cancellation of contracts at sixteen metal working plants, the complete shutdown of one ammonia plant and elimination of 35 TNT lines.⁸ The facilities were converted to other uses and only a year later, when bomb requirements rose, it took seven months to reach 75 per cent of production requirements and nine months to regain full production.⁹

Fuzes presented one of the biggest challenges for the munitions industry in WWII. Picatinny Arsenal was the main producer of fuzes prior to 1940 and Frankford Arsenal installed modern machinery for limited fuze production in the

⁸Thompson & Mayo, U.S. Army in WWII, p. 121.

⁹Ibid.

late 30's. Nearly every manufacturer of fuzes received its technical data on production equipment and manufacturing techniques from those two locations, but it was the sharing of technical data among the old and new commercial producers that was credited with meeting overall production schedules.

Assurance by the US Attorney General in 1941 and again in 1942 that cooperation by the fuze manufacturers would not be considered a violation of anti-trust laws enabled peacetime competitors to freely share their lessons learned in the interest of national defense.¹⁰ This action led to the establishment of 75 different government and industry committees which facilitated the transfer and sharing of information throughout the war.

The capability to share information among competitors is critically restricted today and government staffs at the GOCO ammunition plants are prohibited by law from having contractor employees at the same plant serve on committees with them. There are standby committees that could be activated at mobilization, but legislation would be required to make them legal.

Safety was paramount in the design and operation of the ammunition lines. The nation could ill afford to lose much of its munitions capability from an explosion, so buildings were widely dispersed and efficiency of operation was secondary to safety. Between December 1941 and June 1942, three explosions at ammunition plants killed 83 persons.¹¹ In itself, this record does not appear good, but in a wartime situation, using untrained people handling

¹⁰Ibid., p. 123.

¹¹Ibid., p. 131.

hazardous materials, the record compares favorably with other industries. The result of each accident, however, was often tighter safety restrictions. Many of the lines built during WWII are still part of the munitions base today; their safety-related complexity of layout is still integral to the production process. The assumptions made 40 years ago are treated as facts today.

At the end of WWII, it was decided that the government's ammunition production facilities, which had an acquisition cost of over \$1.8 billion, should be maintained in a state which would allow the initiation of production within four to six months and attainment of full production within eight to twelve months. However, due to "economy measures," inadequate appropriations and personnel shortages the plants fell quickly into disrepair.¹²

At the outbreak of fighting in Korea, only 38 of the original 84 ammunition plants were still available, and it was found that complete rehabilitation of most of those facilities was required. The time needed to start production averaged 13 months. Fortunately, there was still a large inventory of serviceable ammunition from WWII on hand. It had not deteriorated significantly during the five years between the wars.

The reactivation experience for Korea caused concern among those involved and a plan was devised for layaway of facilities that would permit production to begin within 90 to 120 days after mobilization. A good program for preservation and maintenance was devised. Funds in the amount of \$31,500,000 were provided for maintenance of standby facilities which included 44,241,000

¹²R. J. Hammond, Profile on Munitions WWI--SEA, Department of the Army, 1977, p. 106.

square feet of floor space and 70,937 major items of production equipment.¹³

In 1960, maintenance funds were cut in half and by 1964, an austerity program was put into effect. This action was taken at the same time we were increasing our involvement in Viet Nam. Managers apparently cut maintenance funds in favor of weapons systems acquisition. The ammunition industry was not alone in its plight. Maintenance funds were severely cut for troop housing, vehicle repair parts, and other needs. By 1967 when the US had committed large numbers of troops to Viet Nam it was averaging about 18 months to reactivate ammunition production lines and it was realized that the cyclical process of activating and laying away old production lines could not continue when the war was over. The GOCO plants were highly inefficient compared to state-of-the-art in other industries; they were polluting the air and water around them, which adversely affected community relations, and they had become less safe because of deterioration and lack of maintenance. R. J. Hammond, who spent 27 years in the Ordnance Corps, sums up the need for modernization of the plants that was undertaken during and after the Viet Nam conflict:

"As there is no guarantee of peace in this world, we must look forward to the day when this massive complex will have to be reactivated again. Why spend millions of dollars at a time of emergency when supplies are scarce, when skilled manpower is short and in demand, when schedules must be met? This has been the case in the past. To treat layaway and maintenance of idle facilities as a stepchild or a necessary evil, when the very existence of the nation may depend upon the timely reactivation of such facilities is next to treason"14

¹³Ibid., p. 107.

¹⁴Ibid., p. 110.

There is a basic philosophical difference in the mobilization planning now done by the United States and that of our chief adversary, the Soviet Union. The Soviets have been emphasizing quantity of weapons while the US has concentrated on technological advantage and quality.¹⁵ The USSR has a very active weapons base and dual capable plants that can produce either civilian or military goods. Much of the US base is laid away and conversion from civilian to military production would take months or years after mobilization.

The Soviet Union is in a better short-run position vs. the United States because of the former nation's greater inventory of weapons systems, active production base, and rapid mobilization capability. The United States would have a greater long-run advantage due to higher technology, more efficient industrial base, and greater economic staying power. According to Jacques Gansler, "The Soviet Union recognizes this long-run US advantage, and thus would attempt to move as rapidly as possible. The United States must strengthen its position for potential short- and medium-length conflicts."¹⁶ Gansler points out that one way to increase readiness is to decrease production lead times. Other studies have basically led to the same conclusion. In order for the United States to survive a massive Soviet attack, we must have adequate ammunition to support forces in being, and those that would be mobilized, until the industrial base can produce adequate amounts to match consumption.

¹⁵Jacques Gansler, The Defense Industry (Cambridge: MIT Press, 1982), p. 115.

¹⁶Ibid.

The concept is known as "D to P planning." "D-Day" is the day forces are committed to battle and "P" represents the day when current production can supply all ammunition requirements.

CHAPTER II

THE AMMUNITION PRODUCTION COMPLEX

The Secretary of the Army is the Department of Defense single manager for Conventional Ammunition (SMCA). That responsibility is shared through the chain of command with the US Army ARRCOM, which serves as the field operating agency for the SMCA. The SMCA spent nearly \$4 billion for ammunition in FY 1982, adding to an existing inventory of about \$16 billion.¹⁷ To accomplish its mission the ARRCOM has a headquarters staff of over 4,000 employees and an ammunition production network consisting of two government-owned, government-operated (GOGO) arsenals, two GOGO ammunition plants and 25 government-owned, contractor-operated (GOCO) ammunition plants. The plants are the same ones which produced the Army's ammunition for WWII, Korea, and Viet Nam with the exception of three plants acquired from the Navy in 1977 with implementation of the SMCA concept, and one new plant opened in 1983 to produce artillery ammunition near Picayune, Mississippi.

The geographic distribution of ARRCOM facilities is shown in figure 2. Fourteen of the GOCO plants are currently inactive as producers, and over half of the production lines at the active plants are in varying degrees of layaway status. Plants are categorized according to their missions. There are propellant and explosive (P&E) plants, metal parts plants, small arms

¹⁷Representative Jack Brooks, Hearing before a Subcommittee of the Committee on Government Operations, House of Representatives, 97th Cong., November 18, 1981.

UNITED STATES ARMY ARMAMENT MATERIEL READINESS COMMAND (ARRCOM) INSTALLATIONS AND ACTIVITIES

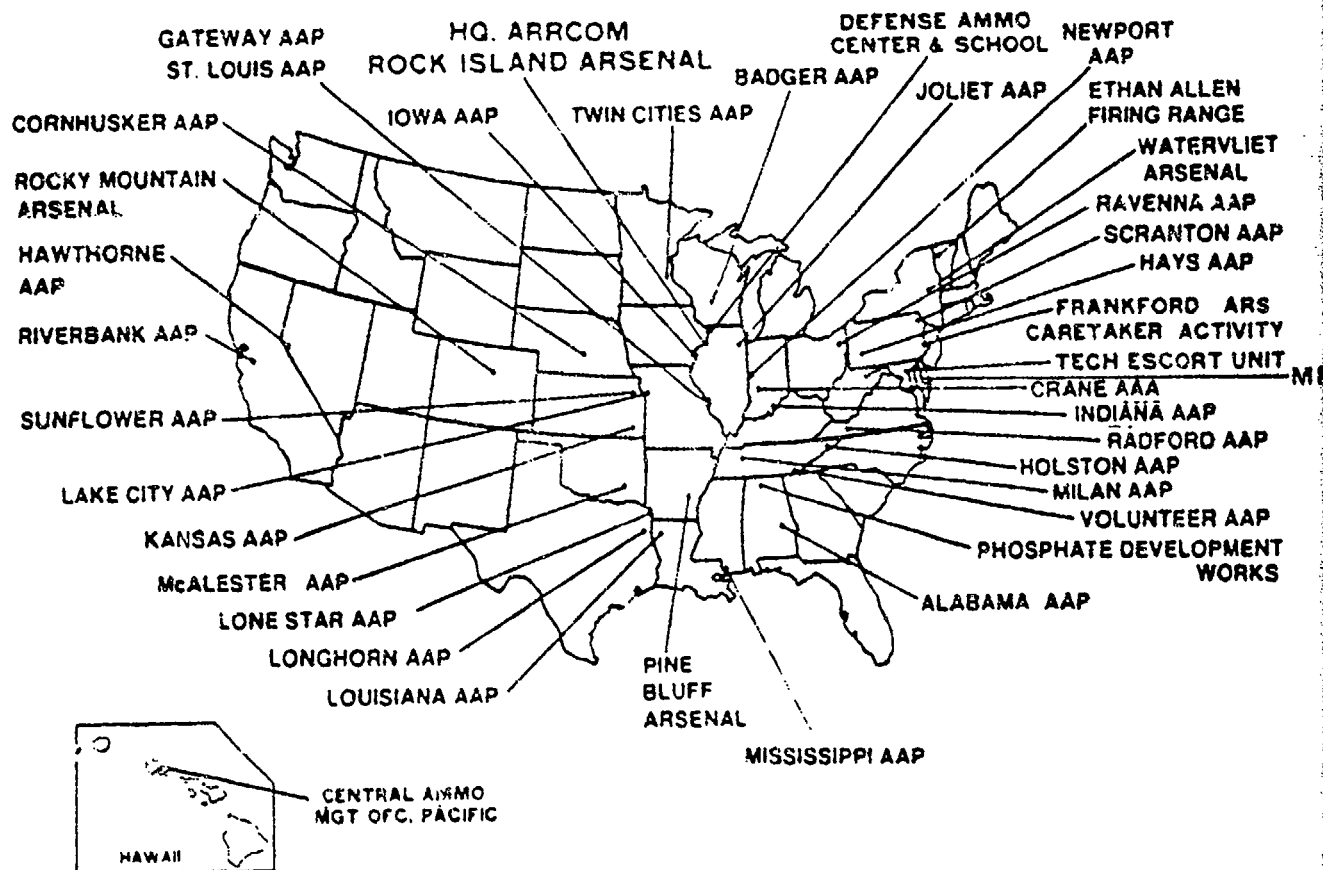


Figure 2. Geographic locations of ARRCOM installations and facilities

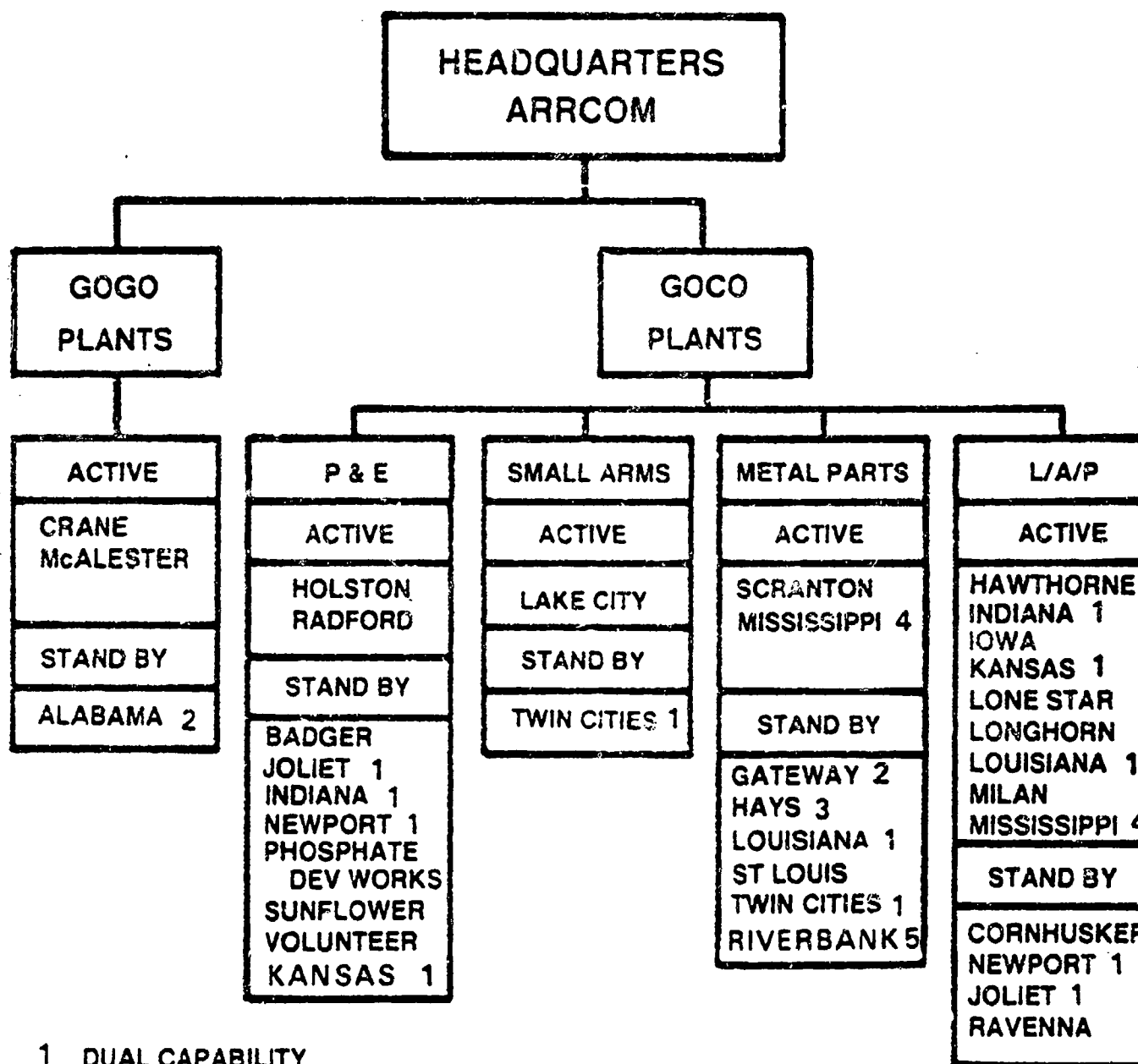
plants, and load, assemble and pack (LAP) plants. Plants are categorized by mission in figure 3. Together, they comprise a replacement value in excess of \$19 billion, employ over 19,000 persons and occupy over 463,000 acres of real estate. This vast complex is owned and controlled by the government because private industry would not be willing or able to manage the capital investment necessary to keep the plants ready when they are not producing.

The ARFCOM philosophy of operation is to maintain a warm production base by producing ammunition for training and war reserve at sub-optimal levels. This procedure insures that some of the plants have adequate resources to increase production rapidly in the event of surge or mobilization while the others are being reactivated. Primary reliance is placed on the operating contractors to maintain the necessary manpower and expertise to facilitate rapid expansion of production.

In addition to providing the cadre to begin expansion under mobilization, the warm base concept permits a lower inventory of war reserve stocks and rotation of those stocks through replenishment of munitions consumed in training, that are sold under the international logistics programs, or which become obsolete or inoperative over time. The warm base is also used to manufacture new items which come into the inventory and to provide low rate production for research and development programs.

As mentioned earlier, most of the ammunition plants used today are the same ones used in 1941. While many of the buildings are the same, most of the production equipment has been up-graded and modernized. A 29-year program to modernize the plants was begun in 1970. The plan, when fully executed, will provide substantially greater production capacity and a relatively safe, pollution-free environment.

U S ARMY ARMAMENT MATERIEL READINESS COMMAND



- 1 DUAL CAPABILITY
- 2 BEING EXCESSED
- 3 LEASED
- 4 UNDER CONSTRUCTION
(DUAL CAPABILITY)
- 5 PENDING INACTIVATION

Figure 3. US Army Armament Materiel Readiness Command.

MANAGEMENT PHILOSOPHY

- MAINTAINING A HOT BASE
- MODERNIZATION OF THE BASE TO THE CURRENT STATE OF THE ART.
- NEED FOR GOVERNMENT OWNED FACILITIES
- CONTRACTOR OPERATED PLANTS ARE MORE ADVANTAGEOUS THAN GOVERNMENT OPERATED PLANTS
- PRIMARY RELIANCE ON CIVILIAN CONTRACTORS FOR PLANT MANAGEMENT WITH ADEQUATE GOVERNMENT INVOLVEMENT

Figure 4

This chart shows the five central principles upon which the ARRCOM management philosophy of the GOCO complex is structured. The first principle, maintaining a Hot Base or Warm Base, is built upon the concept that it is mandatory that key plants be kept operational during peacetime.

The use of private contractors, rather than government employees, to operate the GOCO plants is based on the concept that private enterprise is more flexible at adjusting to schedule changes, and is able to pay workers at rates established by local labor market conditions, rather than government standard rates. There is also competition among the private sector operators to gain additional work through efficient operations. Because ARRCOM uses primarily large business operators with several non-government operations in addition to their GOCO facilities, private enterprise is able to shift management personnel as needed. All of the plants operate on some type of cost plus basis. It can be argued that there is limited incentive for efficient operations when all costs are reimbursed directly and a fee is paid in addition to the cost based on the magnitude of the management function.

To monitor contractor operations and to encourage efficiency, ARRCOM maintains government staffs at the plants. Plant commanders are also contracting officers' representatives and are empowered to represent the principal contracting officers in dealing with the contractors. A typical organization chart showing the government elements at GOCO plants is depicted in figure 5.

MODEL ORGANIZATION STRUCTURE - GOCO ACTIVE PLANTS

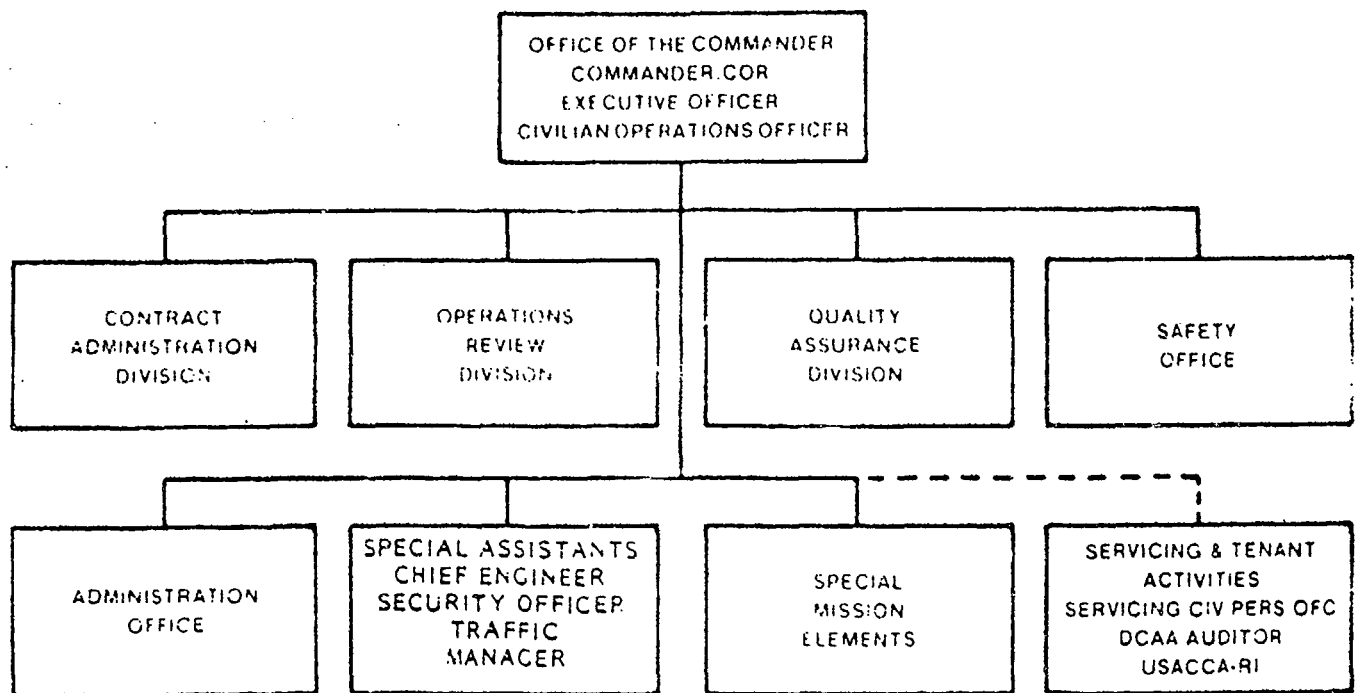


Figure 5. Model Organization Structure--GOCO Active Plants.

CHAPTER III

DECISIONMAKING

Reactivation of the ammunition industry will require thousands of decisions daily from such mundane tasks as whether or not to paint a machine to complex decisions that may require the expenditure of millions of dollars. In either case, the most critical element of the decision may be time. If a decision is put off for lack of information, cautiousness of the decision-maker, or any other reason, precious time could be lost in the race to replenish ammunition stocks expended in combat. Experiments have shown that the greater the number of possible alternatives, the longer it takes to reach a decision.¹⁸ It follows, therefore, that time can be saved by weighting alternatives and establishing criteria for the probability of success of a given action. Public decisionmakers face problems that are not common in the private sector, and what is usually disparagingly referred to as "the bureaucracy" can sometimes delay critical decisions.

Public decisions render the decisionmaker subject to public scrutiny, particularly when large sums of money are concerned. The political process must often be considered as well as the effects on private groups that may have influence in the governmental process. Private business seeks to maximize profits, and as long as they operate within existing laws, management must answer only to the stockholders. In the ammunition industry, particularly the government-owned, contractor-operated (GOCO) plants, decisions may

¹⁸Phillip Goldberg, Executive Health (New York: McGraw-Hill Book Company, Inc., 1979), p. 14.

be even more complex because a decision that maximizes benefit to the government may adversely affect the firm that runs the plant. Often, such situations have to be negotiated among the parties involved at the expense of time.

According to Goldberg, " . . . humans have a limited capacity to receive, process, and remember information Overloading the system can lead to a serious breakdown in performance."¹⁹ Each reactivation decision that can be made in advance can play a part in cutting stress, thus improving performance and reducing reactivation lead times. Models can be developed to simulate the reactivation process, thereby permitting decisions to be made in advance. Every decision involves a certain thought process that begins with defining the problem. Once the problem is adequately described, the decision-maker can then search for alternative solutions. Each alternative must be analyzed before the optimum alternative can be selected. When problems are complex and involve large sums of public money, "gut feeling" will not suffice; some sort of quantitative analysis must be made to justify a decision. Herbert A. Simon²⁰ defines three phases in decisionmaking: "intelligence," searching the environment for conditions calling for decisions; "design," finding and assessing alternatives; and "choice," selecting an alternative from those available. Government solutions to quantitative models of decision situations may require modification for a

¹⁹Ibid., p. 15.

²⁰Herbert A. Simon, The Shape of Automation for Men and Management (New York: Harper & Row, 1965), p. 54.

number of reasons (e.g., complying with service regulations or policy, acceding to political realities, and obtaining the cooperation of plant management and labor unions).

Beyond the actual choice of a course of action lies the problem of implementing that choice. Sometimes the implementation phase raises additional problems which must be solved, or the decision may impact on other areas not previously considered and the implementation must be modified. In government situations, it may not be possible to implement a decision at the optimal moment because funding has not been made available, an environmental impact statement is required, or numerous other restrictions apply.

To make the decision process easier, a model of the situation that will require a decision can be developed. The basic models that could be used in reactivation of ammunition plants would most likely be of production lines, or portions of those lines which produce a particular product. Dr. Christopher McKenna, an expert on quantitative analysis, defines the benefits of a formal model as follows:²¹

1. Makes explicit its problem definition, identifying those aspects of the situation which are and are not included.
2. Supplies a focal point for discussion of the problem, generally leading to a better understanding of the problem itself.
3. Provides the framework for empirical assessment and improvement.
4. Fosters the use of more technical analysis, when appropriate.
5. Can help in keeping the discussion and search for alternatives that are problem oriented rather than personality oriented.

²¹Christopher K. McKenna, Ph.D., Quantitative Methods for Public Decision Making (New York: McGraw-Hill Book Company, Inc., 1980), p. 8.

Ammunition production lines can lend themselves to modeling techniques because they are generally linear in design and rely on successive steps in the production process toward completion of a product. However, multiple inputs of parts, human considerations, machine reliability, energy sources, environmental considerations, and other special conditions all combine to add to the complexity of the lines.

The role of a model in simulating the process of reactivating an ammunition line is to help decisionmakers understand the problems they will face. In private ventures, a model is normally developed immediately before implementation of a course of action, but in the case of reactivating an ammunition line, the date to begin reactivation is not known until an actual emergency occurs. This means that the model would have to be developed and maintained current whenever changes in the decisionmaking environment occurred. This process could be costly and it produces no tangible results while the line remains in layaway. Managers are justifiably reluctant to allocate resources to such programs when money is needed for other programs that would achieve tangible results in the near term.

Until recently, models had to be so simplified that they often assumed away key elements in the decision process. The Venture Evaluation and Review Technique has made a major contribution toward handling complex models. A further explanation of that contribution is presented on page 40. The oversimplification required by former modeling techniques may have soured some managers on the modeling process. There is a real need for an understanding among the managers and the technical experts to gain an appreciation of each other's concerns. Managers have to put more trust in the modeling process and

technicians must understand a good model is not necessarily a panacea to all the ills of the reactivation process. After all, it is the performance of the real production line, not the model that counts.

Managers who elect to build models must face the possibility that a model may be totally ignored by those who could benefit from it. An untimely analysis, erroneous input or simplistic approach may be to blame, or a decisionmaker may have decided to ignore the model before it was even designed.

In the case of the ammunition industry, the decision to use the modeling process must come from the higher levels of the decisionmaking hierarchy if the models are to be of value in improving industrial readiness. In my research, I perceived enthusiastic technicians anxious to explain all the technical aspects of their modeling techniques and skeptical managers, too harried by the press of everyday business to devote the time necessary to develop an understanding of the quantitative process.

CHAPTER IV

REACTIVATION NETWORKS

The production facilities at the various ammunition plants are generally item-specific--that is lines are designed to operate independently of each other. One line can be in total layaway while another is at full production. The greatest impact on the total plant from reactivation of any or all lines is generally on personnel resources and support systems, such as utilities, transportation networks and maintenance capability.

When a holistic approach to plant operations is used, many trade-offs are possible on the allocation of common resources to the production lines. The human mind cannot effectively assimilate the simultaneous impacts that would be created during a dynamic situation such as reactivation for mobilization. Judgements made with incomplete information under pressure may be made more often on subjective criteria rather than quantifiable data, and such judgements can be subject to the prejudices and biases of the decisionmaker, even if they are based on good knowledge of the components that make up the system. For these reasons, it is essential that the best possible "map" be drawn to divide the essential tasks among the available personnel and to develop specific procedures for the reactivation process.

The sheer size of the government-owned ammunition production complex (as indicated in figure 6) makes it highly unlikely that a decisionmaker could be fully aware of all of the ramifications throughout the system resulting from any course of action.

— AMMUNITION PLANTS —

FACILITIES & EQUIPMENT	
ACQUISITION COST	3,577,886,099
REPLACEMENT COST	19,493,473,373
PERSONNEL	
GOVERNMENT	3,820
CONTRACTOR	16,640
TOTAL PLANT ACREAGE	464,112

Figure 6

This chart indicates the value and size of the ammunition plants. The installations that were purchased for some 3.5 billion dollars would now cost over 19 billion to replace. Current personnel strength consists of approximately 3,800 Government staff personnel located on-site and over 16,600 operating contractor personnel involved in production operations. There are 464,112 acres of real estate dedicated to the ARRCOM ammunition manufacturing and storage mission.

Management decisions made during peacetime with limited resources could favor using resources for the betterment of active facilities at the expense of mobilization capability if the needs of laid away facilities are not documented adequately. Accurate, uniform information on the condition and capability of production lines at each of the plants will be extremely important to ARRCOM decisionmakers should it be necessary to mobilize, surge, or start up even a portion of the capability. For example, three load, assemble and pack plants are capable of producing 105mm artillery ammunition. All three lines are laid away and each line has peculiarities that set it apart from the others. The ability to compare the capabilities of each of the lines objectively to determine which was more cost effective for a particular production run could save time and money if only a part of the total production capability were needed.

When facilities are laid away for several years, there is a loss of expertise among those charged with mobilization production. Personnel familiar with actual operation of some of the lines are becoming scarce. Each passing year sees more retirements and transfers of personnel who operated the lines during the Korean and Viet Nam conflicts. The expertise of WWII has largely been lost already. Those plants that were modernized in the 60s and 70s may have had only very short production runs, if any. Personnel who understand those facilities and can operate them without extensive training are not readily available at all plants.

Some of the reasons for developing networks to simulate the production lines include determining if facilities and equipment are adequate; if parts and/or replacements are available for machines (many are over 40 years old);

and whether production lines are complete (there are some lines that were laid away without being fully proved out).

The US Army ARRCOM began a program in 1978 to develop networks that could be used to simulate the ammunition production system. After considerable expenditure of resources and two years of effort, the resultant network was unsatisfactory because there was such diversity of approaches among the plants. The lack of a single networking system rendered the task of assembling all the necessary data too complicated to pursue further.

Following the initial effort, ARRCOM contracted with Day & Zimmermann, Inc., Kansas Division, Stetter Associates, Le Clair, Iowa to develop a standard networking system.

Following the bankruptcy of Stetter Associates, the task fell singly on Day and Zimmermann, Inc., operator of the KAAP, to complete a manual for use by all the plants. The result was proposed ARRCOM Pamphlet 500-1, completed in mid-1982. The pamphlet is a step-by-step procedure for use by personnel at all the ammunition plants to develop networks that will facilitate reactivation under mobilization conditions. The manual has not been published officially, but Kansas AAP, Indiana AAP, Holston AAP, and Riverbank AAP are now developing networks using the manual.

CHAPTER V

INDUSTRIAL PREPAREDNESS MANAGEMENT

Students in the Army Industrial Preparedness Management Course are told the objective of industrial preparedness is to "develop, maintain, retain, and improve the readiness of the Department of Defense industrial base to support the military materiel requirements of approved forces for a variety of contingencies."²² The scope of the Industrial Preparedness Program (IPP) includes industrial preparedness operations (IPO) and the production base support program (PBSP). The IPO function includes retention, preservation and maintenance of defense industrial plants and equipment. The program also includes assessment of industrial capability, determination of mobilization production schedules, and planning agreements with both DOD and privately-owned plants. The PBSP provides investment in DOD-owned industrial facilities for preservation, maintenance, and modernization.

The DOD depends primarily on the private sector as the foundation for production of military materiel. Even the ammunition industry with its GOCO plants is dependent on the private sector for both raw materials and manufactured components. Every munitions item produced has its origins in private industry.

²²US Army Management Engineering Training Activity, Course Book, Industrial Preparedness Management (Rock Island: US Dept of the Army, January 1982), pp. 1-2.

The Department of the Army (DA) is responsible for the preparedness posture of the ammunition industry. Army Regulation (AR) 700-90²³ implements modernization, maintenance, and layaway of plants and equipment for both the active (producing) and inactive (laid away) production base.²⁴

Policy promulgated by AR 700-90 states that government-owned plants and arsenals will provide a reserve of skills and technology in manufacturing military items to assist private industry during the initial phases of mobilization. Government plants are to maintain full mobilization capability to produce military items (e.g., ammunition) for which there is no industrial counterpart.²⁵

The Army Materiel Development and Readiness Command (DARCOM) executes and manages the AIPP for DA. The Production and Industrial Preparedness Division of DARCOM has staff responsibility for the AIPP. The division manages all resources that support industrial preparedness operations. It also assures that all IPP elements are integrated and directs development and implementation of AIPP automatic data processing systems.

The DARCOM, like Headquarters, DA is primarily a policymaking and control headquarters. The DARCOM major subordinate commands are responsible for day-to-day industrial readiness operations. Headquarters ARRCOM is responsible for implementing industrial preparedness measures for the ammunition industry. The specific list of functions in which ARRCOM plays a

²³Army Regulation 700-90, Army Industrial Preparedness Program (Washington: US Dept of the Army, 15 March 1982).

²⁴Ibid., p. 1-1.

²⁵Ibid., p. 1-2.

part is extensive. For reasons of brevity, suffice it to state that all planning, programming, reporting, analysis and correction of deficiencies in the preparedness posture of the ammunition industry, both government-owned and contractor-owned, is managed by ARRCOM. This is an awesome task, especially since the mobilization capability of the United States is a dynamic, not a static entity. Every time a defense contractor gets a new order, be it military or civilian production, the impact of that new order must be assessed against mobilization requirements. Many contractors and subcontractors are small businesses. Acquisitions by larger companies, change of product lines, and even bankruptcies are more frequent in small businesses than large ones.

The government-owned facilities themselves present a formidable task in keeping essential facilities ready for mobilization. The chart following indicates the scope of the preparedness program.

Figure 7

POTENTIAL SCOPE OF WORK

PLANT ACREAGE	464,112 ACRES
NO. OF BUILDINGS	27,989
FLOOR SPACE	87,481,835
MILES OF ROAD	3,516
MILES OF RAILROAD	1,630
IPE	23,814 (APPROX.)

To maintain its cognizance over the vast complex that affects industrial preparedness, the DOD requires a number of reports on the status of plants and equipment. Development of the information for those reports affecting ammunition is the responsibility of the ARRCOM. There is considerable concern within the ammunition community that current reporting systems are inadequate. The true capability of many planned private producers is unknown and even the GOCO ammunition plants have been found to have schedules arbitrarily established and agreed to that are physically impossible to meet within specified times. An example concerning the Kansas AAP lead azide facility is mentioned in a later section of this report. Many contractors and DOD personnel alike consider the system using DD 1519 reports filed by contractors inadequate to provide the information needed to make decisions.

Munitions production for the past several years has been driven by budget limitations rather than military requirements. It is safe to say that insufficient munitions are being produced to meet stockpile objectives which are based on threat and estimated consumption data. It therefore follows that if the stockpile is inadequate, either consumption must be constrained, or the time needed to reactivate production lines must be shortened. Today's weapons have considerably higher rates of fire than WWII weapons and unless constraints are used, many types of ammunition would soon be expended. For example, if all A-10 aircraft in the inventory were to fire their weapons at maximum rates of fire for four minutes, they could expend a year's worth of 30mm production at current capacity. More 30mm weapons are being added to the inventory without a corresponding increase in ammunition production capacity. If WWII experiences in creating new capacity are still valid today, it would

take about 18 months' lead time to double 30mm production. It is obvious that the aircraft will be allowed only a few seconds of fire per sortie to extend the useful life of the aircraft, yet it is questionable whether either stockpile or production capacity is adequate to support the number of aircraft in the inventory. It would be possible to extend the VERT-3 analysis beyond the reactivation of ammunition lines to analyze the alternatives and costs of possible tradeoffs between weapons systems and ammunition.

The problem of relying on the DD Form 1519 reports to assess production capability is that there are no probabilities indicated for a particular plant or contractor to be able to produce quantities specified in the times required, because it is assumed that all resources will be made available when needed. A full assessment of capability would be costly and there is no incentive for a contractor to expend the resources for a complete analysis of his capability when he is uncertain if the effort will ever pay off. Patriotism or sense of duty may cause some contractors to expend extra resources, but there is no evidence that the DD 1519 system is more than a "paper exercise." In the words of the Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness: "There is little realism and no contractual commitment in the 'DOD 1519' process."²⁶ By merely submitting a form with some "best guess" figures, the contractor derives the same benefits as if he did a complete analysis of his capability.

²⁶Office of the Under Secretary of Defense for Research and Engineering, Report of the Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness (Washington: US Dept of Defense, January 1981), p. 54.

Each of the government-owned ammunition plants maintains an Industrial Preparedness Plan (IPP). Basic guidance for the IPP is contained in DOD Instruction 4005.3, 28 July 1972 and AR 700-90. Instructions are promulgated in DARCOM Circulars 700-12 and 700-13. The plans are used to identify capabilities and readiness and to provide capacity information for the Program Objectives Memorandum (POM). In the event of mobilization the IPP would be used to "Identify planned production and maintenance facilities."²⁷

Equipment needed for mobilization production is maintained in Plant Equipment Packages (PEP). Commanders responsible for PEP are required to verify the continuing need for the equipment annually. In addition, it is necessary to assess the reactivation lead time for meeting production requirements, identify equipment voids and determine the capability of the equipment to perform as required. All the above actions must be done annually and reported to the US Army Industrial Base Engineering Activity (IBEA). The IBEA is responsible for overall management of PEP and keeps condition records, coordinates PEP upgrading and insures that condition assessments are made of PEP before upgrading. I was unable to establish any direct interrelationships maintained among various PEP. The locations and conditions of all the packages are known, but the effect of diminished capability of a given PEP on the rest of the system is not assessed. For example, let us assume that a particular PEP due to age deterioration is able to produce only 100 units a day instead of a previous capability of 150. One might logically conclude

²⁷Headquarters, US Army Development and Materiel Readiness Command Circular 700-13, Army Industrial Preparedness Program--Production Base Plan (RCS: CSCRD-163) (Washington: 20 August 1979), p. 2.

that funds should be spent to rehabilitate the equipment so it can again produce 150 units. What is not obvious under the current system is the probability that other elements of the line can still support 150 units, or whether there are other alternatives to upgrading the particular PEP. A network analysis of the entire line, followed by a computer-generated probability of success using the VERT-3 system could aid in the decision process.

CHAPTER VI

VENTURE EVALUATION AND REVIEW TECHNIQUE

To explain what VERT is, it is necessary to start by explaining what VERT is not. The acronym itself can be misleading since many managers have heard of PERT and GERT and assume that VERT is another version of those methods. All three systems are networking techniques, but there the similarity ends. PERT, the acronym for Program Evaluation and Review Technique, was applied by the US Navy beginning in 1958 in planning and executing the Polaris program. The system was credited with playing a significant role in reducing the time it took for the system to become operational.²⁸ PERT is a sequential list of activities required to perform a particular task. Often diagrams using PERT would begin with a completed project, then work backwards to the start. All activities begin and end with an "event" or "milestone" which signifies the end of one phase and the beginning of another.

Using the PERT network, each person responsible for completing a particular task estimates the completion time for that activity. The expected time is the average or mean time estimated for the activity and it may or may not be the most probable time. A discrepancy arises when the differences between the most optimistic, most pessimistic, and the most likely times are not equal. Probabilities of the likelihood of any of the times are not

²⁸Richard A. Johnson, Fremont E. Kastand, and James B. Rosenweig, The Theory and Management of Systems, 2d ed. (San Francisco: McGraw-Hill Book Company, Inc., 1962), p. 323.

provided by PERT and thus the probability of the most likely estimate is not a part of the system. PERT is known as a deterministic method.

The use of PERT spread rapidly following its use in the Polaris system and in the 1960s found wide use by the Department of Defense, NASA and private industry. PERT is a useful tool, but PERT is to VERT what the abacus is to the modern computer. It simply cannot do the same job. There were refinements to the PERT system, such as PERT/Cost, which added the dimensions of cost to the completion of each activity and PERT/Reliability, a tag-along which considered the reliability of the product of each task. Neither of these, or other variations overcame the limitations of PERT.

The Graphic Evaluation and Review Technique (GERT) gained popularity in the decade of the 70s, and added a new dimension to network analysis. GERT has significant advantages over PERT in that GERT networks may contain both deterministic and probabilistic branches. Probabilistic branches emanate from "nodes" which are decision points in the network. The stochastic ability of GERT is its major advantage over PERT. Through simulation and trial, the probability of an event occurring can be estimated. GERT also has the capability to include cost information and repetitive or recurring events. Unlike PERT, GERT can consider both optimistic and pessimistic outcomes²⁹ and determine the probability of each occurring. GERT is limited, however, in the treatment of cost. Like PERT, GERT treats cost as a non-decisive element. A manager

using GERT cannot determine the outcome of allocating varying amounts of the budget to different activities to determine the changes that would occur to the outcomes.

With that limited treatment of PERT and GERT, we can now move to VERT. The Venture Evaluation Review Technique, like GERT is a stochastic method which can simulate an event through an unlimited number of iterations to determine the probability of a given course of events occurring. VERT, developed by Gerald L. Moeller in the 70s, is still developing. The full capability of the technique is not yet known. Because VERT can treat parameters of cost, time, and performance on nodes and arcs, it has major advantages over GERT. VERT is designed as an open-ended and comprehensive system that establishes relationships among network parameters. The flexibility of its nodes is the major strength of VERT in representing the real world. It allows performance to be entered into the network in numerical terms rather than merely as total alternatives.

Improvements to VERT have occurred in the decade since its inception. VERT-2 was completed in 1979 and VERT-3, the third generation, a completely new program, was published in 1982.³⁰ In VERT-3, the capability of mathematical relationships has grown to the point where flows can be isolated, started, stopped, or altered in nearly any conceivable way.³¹ VERT-3 has

³⁰Sang M. Lee, Gerald L. Moeller, and Lester A. Digman, Network Analysis for Management Decisions (Boston: Kluwer-Nijhof, 1982), p. 33.

³¹*Ibid.*

more nodes than its predecessors and also has the capability to automatically determine priorities of processing for cost, time, and performance input when mathematical dependencies are created on an arc.

Some attributes of VERT-3 include:³²

1. Capable of constructing deterministic and/or stochastic models.
2. Provides for present value discounting.
3. Cost, time, and performance have equal analytical status.
4. Data can be entered via histograms.
5. Constraints on time, cost, and performance can be applied directly.
6. Offers both optional and critical path analysis.
7. Computes the path cost as well as the overall network cost at each node.
8. Can be updated by persons without knowledge of machine language.
9. The computer program offers automated error analysis and a full listing of the network on encountering simulation breakdown.
10. All data resides in the core, making computation very rapid.

³²Headquarters, US Army Armament Materiel Readiness Command, "VERT Briefing," 1982.

CHAPTER VII

OPERATIONS WITH VERT

Now that the basics of what VERT is have been explored, it's time to look at the way in which VERT works. It is a computer-based technique that requires 140k bytes of computer memory to run the program. A large, main-frame computer such as the IBM 350 is needed. The program uses the FORTRAN IV language and computer programming specialists and analysts are needed to run it. The technique is complex, but it allows the modeling of extremely complex decisions that previously were beyond the capability of other modeling techniques. The third generation, VERT-3, uses two basic symbols to structure the network model. Nodes, represented by rectangles, indicate milestones or decision points, while lines, called arcs, are used to portray time consumed, cost incurred and performance generated while completing the particular activity. The VERT-3 network is essentially a flow diagram in which the nodes channel the flow and arcs carry the flow between the output nodes and input nodes. The schematic in figure 8 represents a simple network.

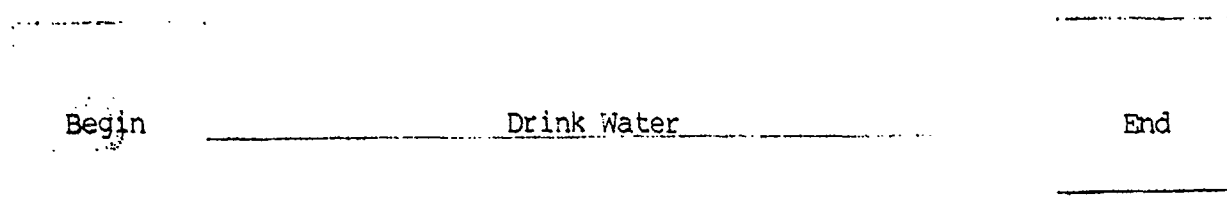


Figure 8. Network to Drink Water

The simple network in figure 8 depicts the steps necessary to drink a glass of water. "Begin" and "End" are nodes. The arc represents action that must be completed. Reactivating an ammunition production line is much more complicated than drinking water, but a complex network is merely a collection of interacting simple networks. Before you could obtain the water it was pumped, purified and transported through a network of pipes. Chemicals, filter equipment and energy had to be procured and used in a certain manner to produce a glass of water from your tap. We could add networks depicting the production and distribution of the pipe and pumps used, perhaps tracing them all the way back to an iron ore mine. Any network can become complicated very quickly and until VERT-3, it was difficult to build network complexities into computer models.

Performance in a VERT network can be modeled in terms of any meaningful unit of measure such as quantities produced, cost incurred, or even a dimension-less index that combines the diverse characteristics (e.g., weight, mobility, size, reliability) that may be needed to fully define a reactivation situation.³³

Arcs and nodes may both be used to represent time, cost, and performance attributes, but they function differently. Arcs are used to convey both primary and cumulative values for probability of successful completion, cost, time and performance, but nodes have only cumulative values associated with them. The primary set represents time, cost and performance data for a

³³Gerald L. Moeller and Lester Digman, "Operation Planning with VERT, Operations Research, Vol. 29, No. 4, July-August 1981, p. 679.

particular activity, while cumulative values represent the total cost, time and value data to that point in the network. It is necessary to use identical units of measure throughout the network. For example, days cannot be used in one node and months in another. Likewise, cost would be measured either in hundreds or thousands of dollars throughout.

Every network requires logic. The VERT-3 network uses input and output nodes to define logic. A VERT-3 node can use split-node logic with separate input and output logic that enforces specific types of input and output operations. There are four basic input logics and six basic output logics available for the split logic nodes. The reactivation networks in ARRCOM Pam 500-1 uses all four input logics, but only three of the output logics.³⁴

The network depicted in figure 9 is taken from ARRCOM Pam 500-1 and represents a more complex network. The "M-12 Widget Manufacturing Line" includes the major types of nodes used in the VERT-3 networking system.

³⁴Headquarters, US Army Armament Materiel Readiness Command, Pamphlet 500-1, "Emergency Planning Reactivation Networks," p. 17.

M-12 WIDGET MANUFACTURING LINE NETWORK OCWB00000
REFERENCE ACWB00005

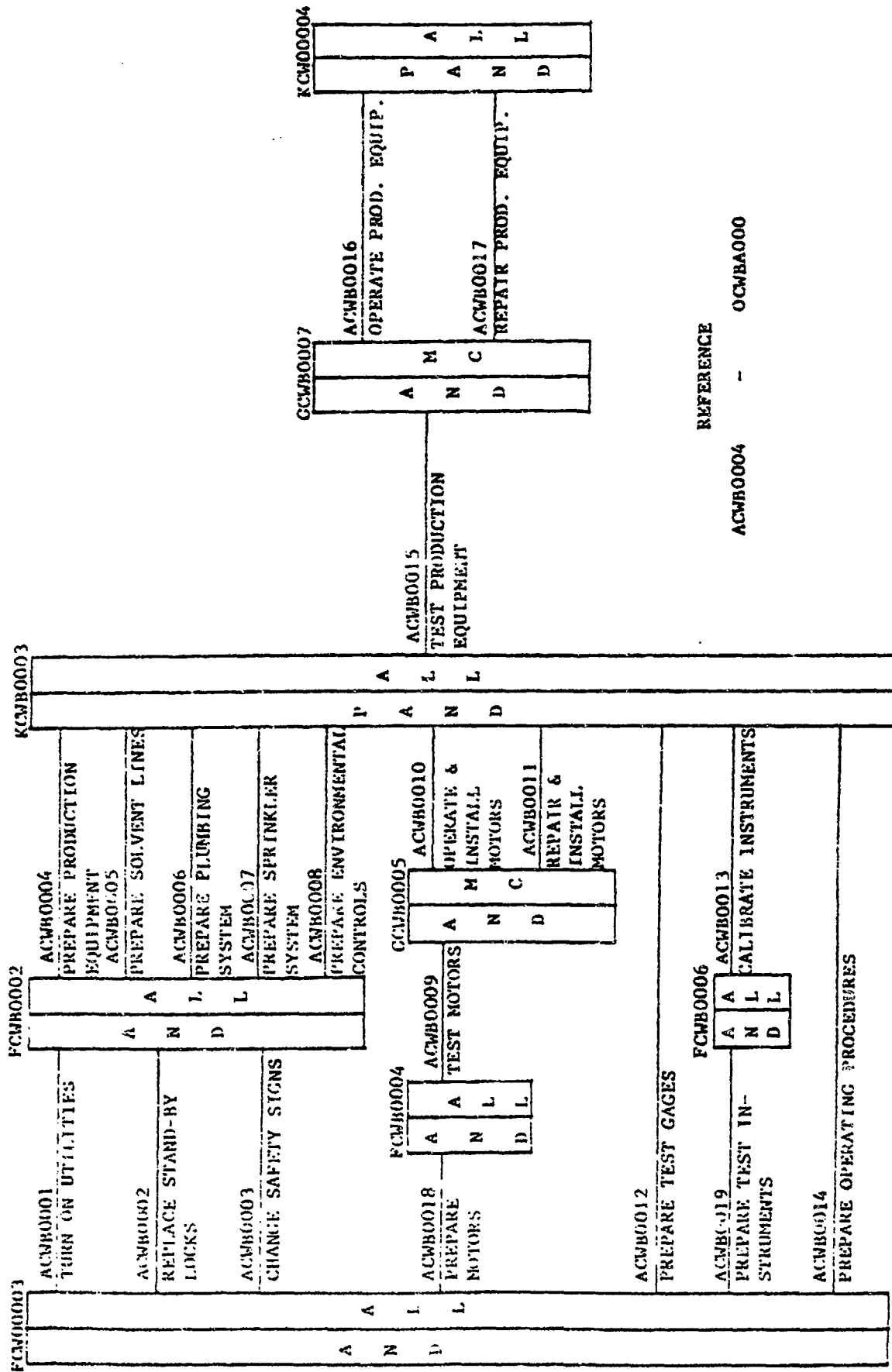
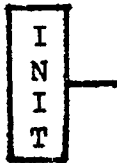


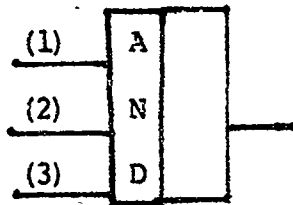
Figure 9

The network begins with "INITIAL" input logic:



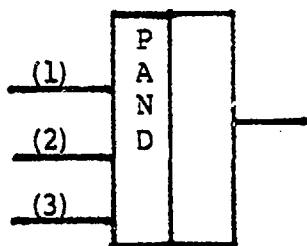
It is the input logic to begin the network. Since flow begins here, it requires no input arcs.

Another type of input logic is "AND".

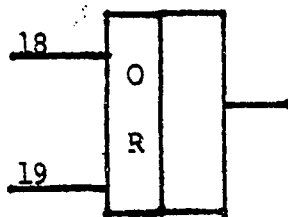


The AND nodes used in the widget example are represented by rectangles which are divided in half by a vertical line. The left half represents input to the node, while the right half represents output. In this example, all three input arcs must be completed before the network flow moves to the output side of the node.

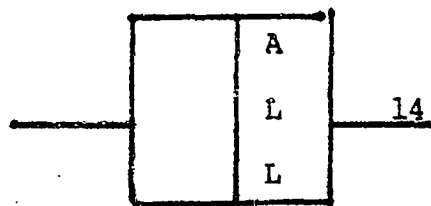
The "Partial And" (PAND) node is similar to the AND node, except that not all input arcs have to be completed before the flow moves to the output side of the node.



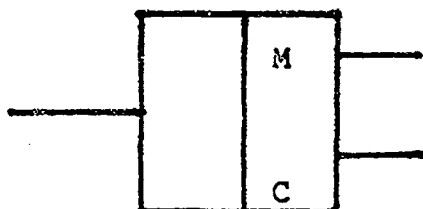
In the widget example, arcs leading from node "D" were complementary arcs. Only one or the other can be completed, thus the input node to which they run is designated a PAND node.



"OR" nodes allow flow to continue as soon as input is received on any of the input arcs. In the widget example, flow would move into the termination node whenever input was received on either arc 18 or arc 19.

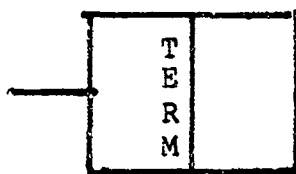


Output is indicated on the right side of the node. The "ALL" output logic signifies that once the input logic has been satisfied, all output arcs emanating from the node are activated.



Monte Carlo (MC) logic is more complicated than the other logic types. It is used when several events may occur as a result of a previous action. The term, "Monte Carlo" is used because there is chance involved in determining the ultimate output. When an MC node is

encountered, the computer can only recognize one active arc at a time.. Several iterations are then run through the computer to determine the effect of chance on each of the arcs emanating from the MC node. In the case of the reactivation network, 500 iterations are run. In the network in figure 4, let us assume that the team which designed the network determined that out of 100 motors, 80 would work and 20 would require repair. A probability of .8 is then assigned to arc 14 and a probability of .2 would be assigned to arc 16. The decimals on all arcs must add up to exactly 1.0.



The final output node actually has no output. It is the terminal (TERM) node. It simply means that the end of the network has been reached.

CHAPTER VIII

WHAT NETWORKS CAN ACCOMPLISH

The experience of the past shows that when the United States was hard pressed to produce munitions, it was able to react in a timely and effective manner. Our industrial capacity was second to none in WWII, and we have always been able to out produce our enemies. Yet, our success in itself could ultimately prove our worst enemy if we rely on past successes and fail to prepare for the future. It is generally conceded that less preparation time would be available in future conflicts than was true of the past. Also modern weapons are capable of expending ammunition at rates undreamed of in past wars. For a while, we neglected our conventional arms in favor of nuclear weapons, but each time we turned to nuclear weapons and intercontinental ballistic missiles as the means to protect us from our enemies, we soon realized that our strategic capability is of little value unless we are willing to risk our entire society to nuclear holocaust. As a result, we now have a standing military of over 2,000,000 persons and are prepared to fight in a variety of situations, nearly anywhere in the world with modern, high technology conventional weapons.

Because the nation's resources are finite, we must reduce costs wherever possible. One way to keep peacetime costs down is to minimize the amount of ammunition we keep in war reserve and to minimize the amount spent on maintaining our munitions production base. The dilemma that must be faced is that if we run out of ammunition before we are able to produce more, we would likely lose the war, or be forced to employ nuclear weapons.

Past decisions involving the ammunition production base were often made without adequate information. The experience of WWII indicates that too much capacity can lead to waste and inefficiency and too little capacity limits the ability of commanders to perform their missions. But we cannot live in the past and survive. Innovations and new policies must be developed to create dynamic planning and systems that are able to keep up with the state-of-the-art. The right decisions require correct information. The objective is to build a flexible production capability that can be operated with optimal efficiency for whatever production rate is mandated.

Because of its ability to compare cost, quality, and quantity variations, the VERT-3 system can determine the effects of new production equipment, compare different types of proposed new equipment, and establish cost relationships among alternatives before a decision is made to install, procure or modify any equipment. New advances in technology can be analyzed for applicability to a particular production line at very low cost compared with the "try it and see" technique that has sometimes been used in the past. It is a waste of money to buy equipment to eliminate a "bottleneck" in production if it is not the only bottleneck. Networking can determine such limits in advance and establish a total cost for achieving any desired change in production capability.

Once networks are established, making changes is relatively easy. They can be updated whenever changes in schedules occur, equipment is replaced or buildings are modified. The major advantage of the networking process, however, is that production capability can be compared to requirements and

actions can then be taken to correct any mismatch. The cost to achieve mobilization rates can be compared with the cost of maintaining ammunition inventory.

One of the deficiencies in the DD 1519 report system is that a contractor may indicate a capability to produce a certain item for the Army and another item for the Air Force. It could turn out that he cannot produce both items simultaneously, resulting in failure of one or both services to meet its needs. Networks can solve such problems because they can compute the effects of producing one item with the capability to produce another item.

The House Committee on Government Operations, 97th Congress in its report in March 1982 cited some of the problems encountered during reactivation for Viet Nam, including old loading docks that did not match the dimensions of modern trucks, doorways that could not accommodate forklifts, lack of repair parts for equipment that had not been produced for decades, and lack of personnel who knew how to operate the equipment.³⁵

The report goes on to state that because of all the problems, the Secretary of Defense had to become personally involved in the reactivation of the plants. If networks had existed then, the problems would have been known as well as the costs to correct them. The networking process uses a systems approach, meaning that everything that affects the production, handling, and shipment of ammunition items and their components is considered in the

³⁵U.S. Congress, House, Committee on Government Operations, Defense Department's Failure to Properly Manage Conventional Ammunition, 97th Cong., 2d sess., March 10, 1982, p. 5.

network. The impact of every mismatch in the system can be determined as to probability of occurrence and cost to correct.

A benefit cost analysis, was conducted by Day & Zimmermann, Inc., Kansas Division, based on the results of a computer analysis of the Kansas AAP networks. The results of the analysis are very encouraging from the industrial preparedness standpoint. The goal of the analysis was to reduce lead times for all items except M55 detonators to 100 working days (5 calendar months on a one shift, 5-day week). The time for M55 detonators was set at 60 days because there is currently limited production. On the 700 line, which produces detonators and leads, all times at the start of the analysis were in excess of 190 working days, and some ranged as high as 272 working days. For an investment of \$3,356,150 the most lead times for the ten mobilization items produced on the 700 line could be cut to a third of their current values.³⁶

The cost would be considerably less than the cost to maintain stocks of the items equivalent to the difference in lead times. The analysis further indicated that the production lead times for the 81mm mortar, produced on the 900 line, could be reduced from 220 working days at a cost of \$1,179,650.³⁷

Similar time savings are indicated on other lines by procuring production equipment and long lead-time items now rather than starting the process on M-Day. It was discovered through the network analysis that the Army's only

³⁶Cook, William A., Benefit/Cost Analysis of Kansas AAP Industrial Preparedness Measures, Reactivation Network Analysis Project, Day & Zimmermann, Inc., Parsons, KS, February 1983, p. 7.

³⁷Ibid., p.

lead azide plant, and the only sodium azide plant in the United States could not produce within the established mobilization reaction times. Since nearly every initiating device uses lead azide, this deficiency could be crucial to national security if commercial or offshore sources could not produce the needed quantities until the Kansas plant came on line.

The benefit/cost analysis determined that it would cost \$5,134,000 to reduce lead times to meet mobilization requirements. The accomplishments of the analysis are an indication that networking systems supported by VERT-3 are a viable means to relate time savings to cost. For the first time it will be possible to make decisions on whether to put money into stockpiles or industrial preparedness with a high assurance that the decision will lead to the greatest benefit for the cost incurred.

Another example for the application of the networking process is the construction and use of containerization facilities at the plants. Containerization facilities will provide for the loading of ammunition in standard containers at LAP plants. The containers will be loaded on rail cars and shipped directly to using units. There are many factors which impact on the size and location of such facilities, including production rates, quantity-distance safety factors, availability of suitable land, ability of rail systems to support the required rail cars, and road networks leading to the site. Day & Zimmermann, Inc., Kansas Division, using an analysis technique similar to the networking process for production lines, concluded that the containerization facility scheduled to be built at Kansas AAP could be scaled down considerably. The result of their value engineering change proposal (VECP) was that over \$1.2 million in construction costs could be saved by

modifying the proposed facility. A full analysis of the entire process of loading and shipping containers would probably yield additional savings since the current plan calls for loading the ammunition in trucks at the end of the production line and moving it to the central containerization facility. Rail service already exists to all the production lines and a complete analysis might conclude that direct loading at the production facilities could be accomplished. The possible applications of the networking process are probably limited only by the ability of the plants to perform the required research and analysis.

CHAPTER IX

CONCLUSIONS

An analysis of the networking process led to the conclusion that VERT-3 networking can be of considerable benefit in maintaining the preparedness of the inactive ammunition production lines. It will take greater management effort, however, to make the system work well. The activities currently being pursued at the Indiana, Kansas, Riverbank, and Holston ammunition plants should give a good indication of the potential of VERT-3 networks. The data gained from those plants could then be applied to other plants once the system is perfected.

The biggest obstacle to the success of the program is a lack of knowledge of the reactivation networking process among key individuals in decisionmaking positions. I found no evidence that persons outside of ARRCOM are involved in the on-going effort in other than an unofficial capacity. Likewise, key personnel at the ammunition plants do not know enough about the system to see that resources are applied effectively. These remarks are not made to disparage any individual or office involved. The program simply has been low-key in spite of the fact that over \$2 million has been expended to date.

The lack of initial success of the networking effort was probably due to the failure of ARRCOM to establish goals for the program and to educate the managers that would be affected by it. The first attempt to establish networks was evidently made with good intentions, but lack of command emphasis and few standards by which to operate led to such divergence of product that it was essentially a futile effort from a collective standpoint. It is still

possible to recoup some of the investment because basic data established for the networks at each plant should be largely valid for application to the process established in ARRCOM Pam 500-1. It is unfortunate that the manual was not written before the attempt to design the networks; however, that fact should not be used to condemn the total program. The money spent to date should be considered as a sunk cost and the past failure should not be used as criteria for deciding the future of the program.

Under the present system, the plants do their network analysis and furnish the information to Headquarters, ARRCOM by mail. It is then processed and programmed into the computer. Computer printouts are then mailed back to the plants. Much effort is expended for little gain in that process, and considerable time is lost in mailing the data. The momentum is hard to maintain when an engineer has to wait four to six weeks for feedback on his work. Computer terminals at the plants should be used instead to improve the performance of the system. That action could eliminate extra handling, decrease workload at ARRCOM and allow direct manipulation and update of the data.

It is highly probable that the proper application of the VERT-3 system can eliminate or at least streamline much of the reporting of status that is currently going on. This is particularly true in maintaining the current status of Plant Equipment Packages (PEP). Once a PEP was entered into the network, status reports would no longer be necessary. The process of updating the network would automatically assess the status of the PEP and determine its impact on the total capability of a given production line or plant. Since multiple copies of PEP reports are distributed among DA, DARCOM, IBEA, ARRCOM,

and the plants, considerable handling of cumbersome data elements could be eliminated, allowing more time to correct deficiencies.

There are a wide variety of reactivation situations which lend themselves to VERT-3 networking that can be added to the basic networks. The primary networks involve the production lines, but many factors outside the lines impact on their ability to achieve required production rates. Support functions such as utilities, transportation, shop support, and labor availability all must be added to the networks to achieve optimal value from the networking system.

As was mentioned earlier, all ammunition items are dependent on private industry for raw materials and parts. The present networks assume that the necessary materials will be on hand when they are required. The "government furnished materials" (GFM) are procured by ARRCOM, not the ammunition plants. Central procurement of items common to two or more plants makes economic sense, but the plant managers are not in communication with their suppliers and cannot assess the reliability of inputs which will ultimately make or break the production schedules. Operating contractors currently procure many minor ammunition components and some of the packing materials. The process could be more effective if under mobilization conditions each plant procured all those items that are used only by that plant. Such components could then be added to the plant networks. The next logical step would be to extend the networking process to the contractor-owned plants that supply GFM to the government-owned plants. There would be costs involved in establishing the networks, but once established, they would cost relatively little to maintain

and would give an instant picture of production capability for any given item. They would certainly be more reliable than the DD Forms 1519 used.

To prevent a repeat of the WWII experience mentioned on page 6, which saw massive shifts in production rates, the impact on future capability of changing rates of production could be assessed through the computer model and the optimal path could then be charted to match weapons systems with ammunition production capability. The example cited concerning lack of production capability to support the Air Force A-10 is a matter of simple arithmetic and can be worked out in a few seconds on a hand calculator. Other new systems, such as the Army's multiple launch rocket system (MLRS) and Division Air Defense System (DIVADS) also appear to have rates of fire that cannot be supported by the current ammunition production capability. (If each of nine MLRS batteries fired only 12 volleys a day, they would consume 7.5 million M77 grenades.) Tying the weapons systems to their ammunition support through the VERT-3 process would go a long way toward balancing the number of weapons with the ammunition production means. It is not prudent to spend all available funds for the weapons while leaving funding for ammunition until mobilization. Experience has demonstrated that a minimum of 18 months is needed to begin new production. Assuming a constant number of launchers, an 18-month stockpile of rockets for the MLRS would require over four billion M77 grenades, each costing about \$1.40 to produce. The optimal path is somewhere between no pre M-Day ammunition expenditures and \$4.4 billion for inventory. The VERT network can determine where it lies.

CHAPTER X

RECOMMENDATIONS

The following recommendations are made based on the data available for the writing of this report. They are not constrained by the availability of funds or personnel, and it is not presumed that the conclusions reached are the only possible solutions to the problem of reactivating laid away ammunition production lines.

The greatest need facing the ARRCOM is to establish formal goals for the networking program. Without goals, money could be spent unwisely and the end result could still be something that falls short of the need. The general lack of understanding of the networking process among government personnel at the ammunition plants might also be ameliorated if goals were established. Formal goals would create the need for more involvement by those personnel who would be required to implement the reactivation process in the event of mobilization.

The proposed ARRCOM Pamphlet 500-1 was completed in mid-1982, but the pamphlet has not been officially published. This lack of urgency is taken by many as another sign that the program does not have the support of the headquarters and therefore is not worthy of time or resources. The pamphlet should be published and promulgated as soon as possible. When published, it should contain the overall program goals.

The possibility of substituting networks for many of the existing readiness reports, such as DD Forms 1519, should be explored in depth. Resistance can be expected, since eliminating the reports could threaten some well-intrenched

bureaucracies. It could turn out that information that is now considered essential to the industrial readiness program would not be needed after implementation of interrelated networks.

The current method of mailing data from the plants to ARRCOM Headquarters and mailing computer read-outs back to the plants should be replaced by direct terminal links. This would save time and money while making the program more efficient.

It would not be prudent to extend the networks to other plants until the three plants currently developing networks have completed their efforts and analyzed the results. Eventually, however, the networks should be extended to all the government plants, then to the key contractor plants with Plant Equipment Packages (PEP). The VERT networks could also be extended at each of the plants by appending PERT networks at various points to establish requisite times for accomplishment of certain tasks. At some future time, all producers which have a "downstream" effect on ammunition production should be included in the networks.

A process to translate computer-generated data into management information is needed. The present format does not generate information that most managers will readily understand.

Training on the VERT networking methodology should be expanded for personnel who enroll in the industrial readiness courses offered by the Army Management Engineering Training Activity (AMETA).

The use of VERT to determine the optimal mix of weapons systems and ammunition should be explored. It seems that a program could be developed that would enhance an objective evaluation of the proper application of available funds between weapons systems and ammunition.

ACRONYMS AND ABBREVIATIONS

AAP	Army Ammunition Plant
AIPP	Army Industrial Preparedness Plan
AMETA	Army Management Engineering Training Activity
AR	Army Regulation
ARRCOM	US Army Armament Materiel Readiness Command
DA	Department of the Army
DARCOM	US Army Development and Materiel Readiness Command
DOD	Department of Defense
GERT	Graphic Evaluation and Review Technique
GFM	Government furnished material
GOCO	Government owned, contractor operated
IBEA	US Army Industrial Base Engineering Activity
IPO	Industrial Preparedness Operations
MLRS	Multiple Launch Rocket System
PBSP	Production Base Support Program
PEP	Plant Equipment Package
PERT	Program Evaluation and Review Technique
SMCA	Single Manager for Conventional Ammunition
VECP	Value Engineering Change Proposal
VERT-3	Venture Evaluation and Review Technique, Third Generation

BIBLIOGRAPHY

BOOKS

Jacques S. Gansler, The Defense Industry (Cambridge, MA: MIT Press. First Paperback Edition 1982).

Philip Goldberg, Executive Health (New York: McGraw-Hill Publications Company, 1979).

Richard A. Johnson, E. Fremont, and James E. Rosensweig, The Theory and Management of Systems, 2d ed. (San Francisco: McGraw-Hill, 1967).

Christopher K. McKenna, Quantitative Methods for Public Decision Making (New York: McGraw-Hill Inc., 1980).

Lee M. Sang, Gerald L. Moeller, and Lester A. Digman, Network Analysis for Management Decisions (Boston: Klvwer-Nijhoff Publishing, 1982).

Richard E. Trueman, An Introduction to Quantitative Methods for Decision Making (San Francisco: Holt, Rinehart, and Winston, 1977).

PERIODICALS

Bruce Horovitz, "Why Corning is Sticking with MRP," Industry Week, Jan 25, 1982, pp.

Edward E. Elko, and T. R. Stvelpnadel, "The 30-MM GAU-8 Ammunition Story", National Defense, September 1981, pp. 50-54.

JOURNALS

Eric C. Ludvigsen, "Rebuilding for the 1980s with an Eye on 2000", Army Green Book 1982-83, Association of the U.S. Army, October 1982, pp. 248-408.

Greg A. Mann, "VERT: A Risk Analysis Tool for Program Management", Defense Management Journal, May-June 1979, pp. 32-36.

T. H. Mattheiss, Gerald L. Moeller and James Kilar, "Improving Industrial Readiness with Venture Evaluation and Review Technique", Interfaces Vol. 12, No. 1, The Institute of Management Sciences, February 1982.

Eward C. Meyer, GEN, "Time of Transition; A Focus on Quality", Army Green Book 1982-83, Association of the U.S. Army, October 1982, pp. 18-24.

Gerald L. Moeller, and Lester A. Digman, "Operations Planning with VERT", Operations Research, July-August 1981, pp. 676-697.

REPORTS

George Bevis, Closed Loop MRP at the Tennant Company (Tennant Co., Minneapolis, MN, 1981).

William A. Cook, P.E., Benefit/Cost Analysis of Kansas AAP Industrial Preparedness Measures, Reactivation Network Analysis Project, Day & Zimmermann, Inc., Kansas Division, Parsons, KS, February 1983.

U.S. GOVERNMENT DOCUMENTS

Comptroller General of the United States, Review of Readiness Status of Idle Ammunition-Production Facilities, Report to Congress (Washington: June 1966).

Comptroller General of the United States, Report to the Congress, DOD's Industrial Preparedness Program Needs National Policy to Effectively Meet Emergency Needs (Washington: U.S. Government Accounting Office, May 27, 1981).

Harry C. Thomson, and Lida Mayo, The Ordnance Department: U.S. Government Printing Office Procurement and Supply (Washington: 1960).

U.S. Congress. House. Committee on Armed Services, The Ailing Defense Industrial Base: Unready for Crisis, Report of the Defense Industrial Base Panel (Washington: U.S. Government Printing Office, December 31, 1980).

U.S. Congress. House. Committee on Government Operations, Defense Department's Failure to Properly Manage Conventional Ammunition (Washington: U.S. Government Printing Office, March, 10, 1982).

U.S. Congress. House. Subcommittee of the Committee on Government Operations Hearing, Defense Department's Failure to Properly Manage Conventional Ammunition (U.S. Government Printing Office, 1982).

DOD

R. J. Hammond, Profile on Munitions WWI--SEA, U.S. Department of the Army, A Record of Lessons Learned With Ordnance 1950-1977, undated.

Headquarters, U.S. Army Armament Materiel Readiness Command, Briefing Notes, Reactivation Networks, (Department of the Army, Rock Island, IL, 27 Mar 1982).

Headquarters, U.S. Army Armament Materiel Readiness Command, ARRCOM Pamphlet 500-1, Emergency Planning Reactivation Networks, Department of the Army, (Rock Island, IL).

Headquarters, U.S. Army Armament Materiel Readiness Command, ARRCOM's Management of its Ammunition Plants, (Rock Island, IL: U.S. Department of the Army, Jan 1981).

Erling R. Jacobsen, Decision Risk Analysis of Granular Composition B Facility (Rock Island, IL: U.S. Army Armament Materiel Readiness Command, June 1982).

Joint Chiefs of Staff, United States Military Posture for FY 1983 U.S. Department of Defense, (Washington: U.S. Government Printing Office).

Edward V. Karl and William Fedorochko, Jr., A Contemporary Approach to Three Real World Problems: Near Term Readiness Surge, and Mobilization, (Washington, D.C.: National Defense University, 1981).

Berkley R. Lewis, Ammunition, (Washington, D.C.: Department of the Army, 1945).

Office of the Under Secretary of Defense for Research and Engineering, Report of the Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness, (Washington: January 1981).

U.S. Army Management Engineering Training Activity Course Book, Industrial Preparedness Management, Department of the Army, (Rock Island, IL: Fifth Printing, January 1982).

U.S. Army War College, Army Command and Management: Theory and Practice, (Carlisle, Pennsylvania: 1982, U.S. Department of the Army).

U.S. Army Armament Materiel Readiness Command, ARRCOM Facts, U.S. Department of the Army, (Rock Island, IL., 1981).

U.S. Army Armament Materiel Readiness Command. Decision Models Directorate, Venture Evaluation and Review Technique (VERT), U.S. Department of the Army, (Rock IL: Nov 1979. Revised 18 March 1981).

U.S. Department of Defense, Summary Report of the DOD Task Force to Improve Industrial Responsiveness, March 1982. Reprinted by the National Defense University Printing Plant, (Washington, D.C, November 1982).

U.S. Department of the Army, Army Regulation 700-90, Army Industrial Preparedness Program, (Washington, D.C.: 15 March 1982).

BRIEFINGS

Craig Kuriger, Briefing, Armament Industrial Readiness Management System (AIRMS), U.S. Army Armament Materiel Readiness Command, (Rock Island, IL: 1982).

Henry J. Thayer, COL, Briefing, Translating Requirements into Production Capabilities Through Production Base Modernization and Expansion Projects, U.S. Army Munitions Production Base Modernization Agency, 29 November 1982.

INTERVIEWS

Craig Kuriger, Chief, Industrial Base Management Systems Branch, Industrial Readiness Directorate, Headquarters, U.S. Army Armament Materiel Readiness Command, Rock Island, IL, 19 November 1982.

Gerald L. Moeller, Co-author, Network Analysis for Management Decisions, 14 December 1982.

Henry Drescher, Industrial Base Management Systems Branch, Industrial Readiness Directorate, Headquarters, US Army Armament Materiel Readiness Command, Rock Island, IL, 19 November 1982 and 18 February 1983.